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PROJECT SCHEDULING BY A HEURISTIC ALGORITHM UNDER LIMITED RESOURCE IN THE CONSTRUCTION INVESTMENTS

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Abstract

A proper use of the resources has become the prime target of the economy circles nowadays. In this connection, an optimal use of the resources in the construction industry is of a great importance. In a construction project, a vast number of processes are involved and each of them requires many different resources, namely, labor, machinery, materials, finance, etc. The size of the construction projects is relatively large and these projects are fairly complicated. One should not think that the resources are to be available at the desired time and at a prescribed amount during the process of the implementation of the project. Therefore, use of the resources also needs a stage of planning. These projects can conveniently programmed by the so-called resource constrained project scheduling techniques. In this work, an algorithm based on a heuristic approach with priority rules was developed in the Visual Basic language and tested on a project applied to the construction of building for primary school in Turkey. The project comprises 79 activities each involving 11 different resources. Different programs for the cases of constrained and unconstrained resources were developed. The overall period it takes the project to be completed was found to be 226 days for the case of unconstrained resources and 260 days for the case of under constrained resources.

Keywords : Project planning, constrained resources, heuristic methods.

1. Introduction

Project planning is a collection of works involving the order of activities with the due consideration to priority relations and all the other factors [1]. Another definition for project planning is timing of the operations and a multipurpose decision-making problem providing a solution through decision on the allocated resources [2, 3]. From the operational research point of view, project planning is the determination of the best alternative leading to the most-desired solution in terms of at least one criterion. This type of programming comprises the following elements:

- Decision variables, that is, all the variables of which values that shape up during the process of solution, direct to an alternative solution to the problem.
- Constraints, that is, factors limiting the possible values the decision variables can take, and thereby determine the alternatives leading to viable results. Equation constraints, resource constraints and time constraints are typical examples.
- Aims that lead us in deciding what principals are to be taken as the basis of choosing from the alternatives for solution [4].

Nowadays, developed project planning and control methods can be thought to be of two general categories. The first one is the Gantt chart. It is a technique making extensive use of bar graphics and being used in the planning and control of simple projects. The second method is the network analysis. This method is used in the planning of a project composed of a series of interrelated activities.

Project planning aims at the realization of a project, with limited resources and minimum overall cost, while the flow chart structure and network operations are fixed. It is, in a sense, the timing of activities types and the amounts of the resources provided and the speed of and the time allocated for the forcing of capacities.

In cases where the resources are limited, project planning can be carried out in three ways, namely, mathematically, heuristic and meta-heuristic [5].

In most cases in the projects which have complex activities such as construction investment, studies tend to direct to the preference of heuristic algorithms [6]. The heuristic methods are based on a fixed rule, a principle that simplifies the solution, an empirical finding or a simple operation. These methods reach the solution by reducing a large solution set or probability problem to simpler and smaller ones [7]. Mathematical methods generally tend to fail in situations of project planning where the resources are limited. Especially when the project as a large one and the network is complicated, this is the case [8]. Heuristic methods concentrate on two major issues. One is minimizing the [9] time and the other, the minimizing the overall cost [10-14]. Researches have developed algorithm to accomplish these minimizations of these main subjects [15,16,17]. Minimizing the time in the project planning works using heuristic methods can be managed by using simple priority rules. These rules include the fallowing articles [18-21]:

- The activity that is intrinsically the first is to be given the priority (MRPL),
- Minimum Latest Start Time (LST),
- Minimum Early Finish Time (EFT),
- Minimum Latest Finish Time (LFT),

- Minimum Slack Time (MSLCK),
- Greatest Rank Positional Weight (GRPW),
- Most Total Successors (MTS),
- Resource Scheduling Method (RSM),
- Shortest Processing Time (SPT),
- Worst Case Slack (WCS).

2. Scheduling Algorithm

Steps 1-3 of the project planning algorithm are used for the unlimited project planning models, for cases with limited resources. The algorithm works according to the priority rule is continued Figure 1 [22].

The priority rule of the algorithm is based on the principle that after the starting point of each activity the activity of the longest duration is given the priority over others.

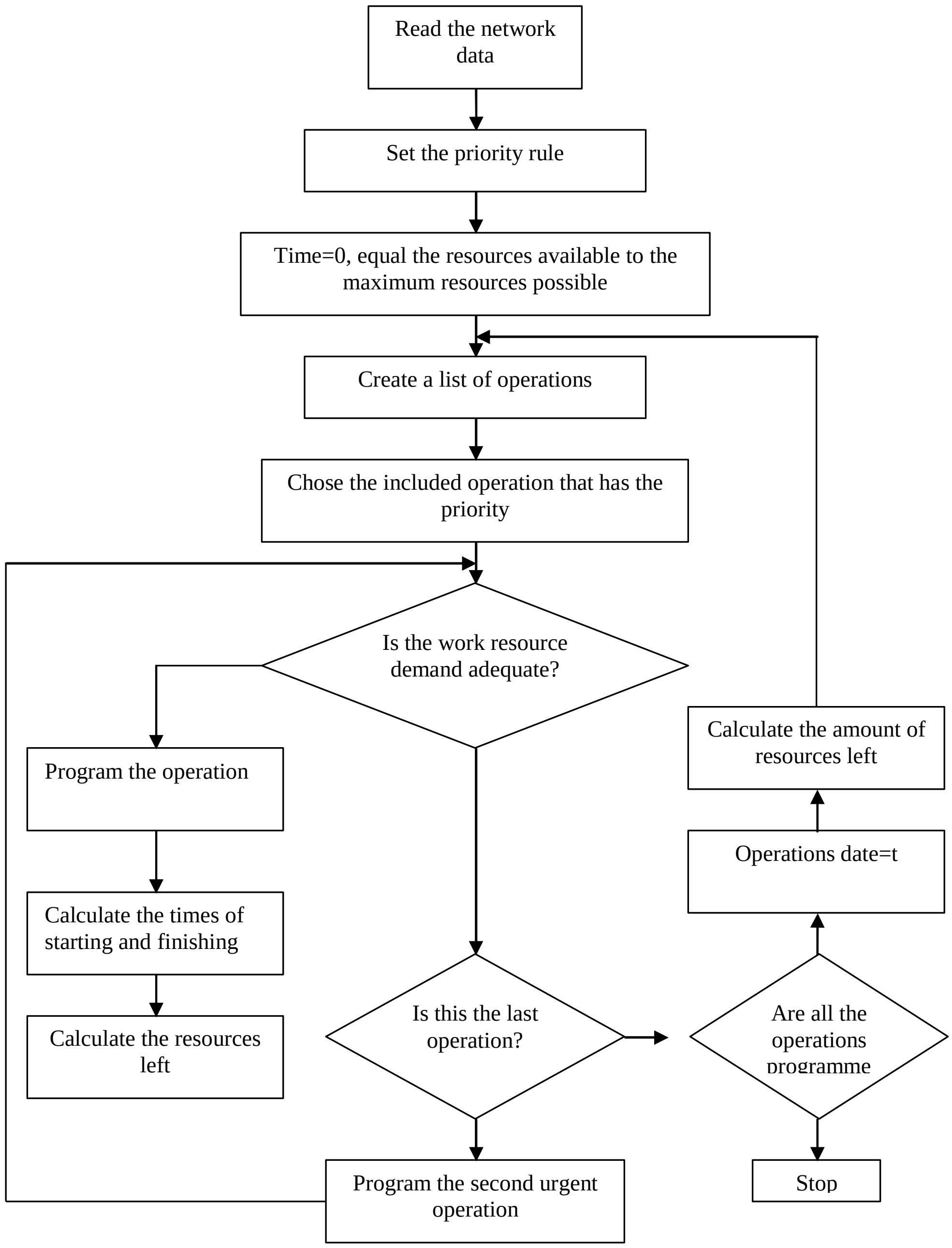

Figure 1. Priority rule algorithm for project scheduling [22]

The working principle of the algorithm is described below:

I. The network is reviewed throughout and the earliest starting and finishing times of the activities, together with the earliest occurrence times of events are calculated.

a. The time at which the first activity started is taken as “0”. Hence, the earliest of the starting times of the activities (ES_{ij}) are fixed.

b. The earliest finishing times (EF_{ij}) are calculated on the bases of ES_{ij}’s and times of duration (t_{ij}).

c. The earliest duration times (T_i^E=max.EF_{ij}) for every individual event is set if the earliest finish times of all the events dependent of that event are known.

d. The earliest starting times for all the events with known early occurrence times are set as $ES_{ij}= T_i^E$. Therefore, earliest starting-, finishing- and the earliest occurrence times of all the events become known.

II. The network is followed, from the buttom to the top, once again, the latest starting-, the latest finishing- and the longest occurring times of all the events are determined.

a. The longest and the earliest occurrence times of the event of the finishing of the whole project are taken to be equal, that is, $T_p^{L}= T_p^E$. Thus, the latest finishing times of all the individual events that make up the whole project are determined, that is, $LF_{ij}=T_p^L$.

b. The latest starting times for all the activities with known latest finishing times are calculated. Thus, $LS_{ij}=LF_{ij}-t_{ij}$.

c. For each individual activity the latest occurrence time, T_{ij}, is taken as T_i^L= min. LS_{ij}, if the latest starting times of all the dependent activities are not calculated.

d. The latest final times of all the activities dependent on the same individual activity with known latest occurrence time are taken as $LF_{ji}=T_i^L$. Therefore, the latest starting-, finishing- and occurrence times are set.

III. The obtained results in the first two steps are tabulated. The project finishing time is taken as T_p^L. The abundances of every activity are determined as $S_{ij}=LS_{ij} – ES_{ij}$. The activities with zero abundance are named as “critical activities”.

Every effort spent up to know as part of the algorithm is aimed at programming the project for cases of unlimited resources. From this point onwards, those projects with limited resources are considered.

IV. The time spans between the starting and the finishing of all the activities are calculated; $MRPL_{ij}=T_p^E - T_i^E - S_{ij}$; and these times are put in an ascending order on the basis of the values of the activities.

V. The requirement of resources, for an activity, within one unit of time is compared with the amount of resources likely to be made available in that unit and the suitability to the condition, $K_{ij}^n <= K_{max}^n$ is checked. If many problems arise, the project manager is notified.

VI. The time is set to "zero" for the initial calculations. All the activities are regarded as "not planned". The amount of each resource per unit time is taken to be equal to the maximum amount of provision for the same resource. The starting times of all the activities are taken to be equal to the earliest starting time.

$z=0$ (time),

$KT_q^n = n$ The amount of resources available at unit time (q-1,q).

$K^n_{max}= n$ The maximum amount of resources likely to be made available in unit time.

B_{ij} = Starting time (of the activity concerned).

$KT_q^n= K^n_{max}$

$B_{ij} = ES_{ij}$

VII. First line of the list which is arranged according to activities MRPL size (from biggest to smallest) is gone.

VIII. The next activity with the starting time equal to or shorter than the time found is taken. If the amount of resources available are sufficient for that activity, the activity is programmed and if the starting time of the activity is earlier than the time found, it is taken to be the same as the time found; that is, $B_{uw}=z$. Then the step 9 is taken.

Otherwise, return to the beginning of step 8 is required. If a return to the top of the list is concerned, the time is increased by one unit, that is, $z=z+1$, as the provision of resources requires some time, and one step back, step 7 is taken.

IX. For all the resources where the activity concerned is involved, resource allocation for the whole duration of the activity is made and the amount of resource for the stages are decreased according to the following equation:

$KT_q^n = KT_q^n - K^n_{uw}$ $\quad n=1.....x, \quad q=z+1.......z+t,$

uw= Resource allocated activity.

X. The finishing time of the activity is calculated as $F_{uw} = B_{uw} + t_{uw}$.

XI. If the starting times of all the activities dependent on the same individual activity are earlier than the finishing time of the activity for which the resource allocation is made, they are taken to be the same as that time that is, $B_{wj} = F_{uw}$.

XII. If all the activities are programmed, step XIII is taken; otherwise, step VIII is returned.

XIII. A bar diagram of the project is drawn, and a table of consumption for the resources at each stage is prepared.

3. Material and Method

Project models in which the number of activities and resources is large are virtually impossible to be carried out to give the desired performance by mathematical models. In projects involving complicated activities, which are generally the case with construction investments, heuristic algorithms leading to solutions by simple rules are employed. In this work, the steps of a heuristic algorithm suitable for construction projects are considered. The performances of such an algorithm were tested on a sample project. The priority rules used were chosen from among those frequently reported to have been used in the literature. The algorithm of which the operation principle explained in the previous section was written in the Visual Basic Language. The programming was made in the implementation of the main primary schools. Performances for limited resources and unlimited resources were evaluated.

4. Implementation

The project under implementation, consist of two blocks which have 3072 m² covered area. One of the blocks has also a basement. Both blocks have ground floor and normal floors. The plan and sections of the project is shown in Figure 2.

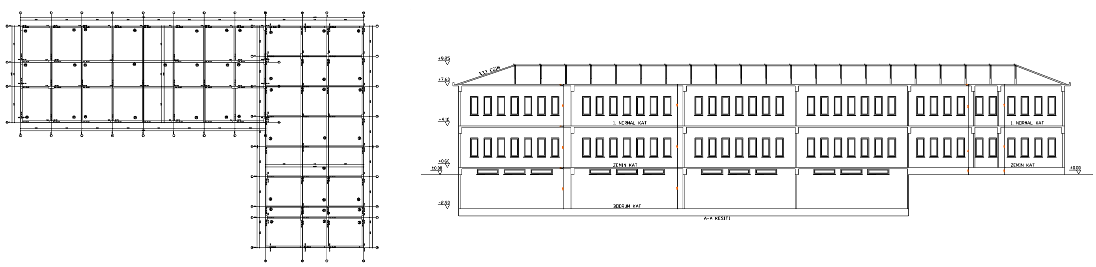

Figure 2. Project plan and cross section of project

The project comprises 79 activities and 11 different resources being used in each activity. The data relating to the project, number of resources used, daily resources constraints and other information are given in the appendix. The time specified by the Ministry of National Education is 330 calendar days. The period to be spent out of work due to winter conditions is 60 days and the time allocated for plumbing and cable installation and finishing works is 30 days. Half of the remaining 240 days time is reserved for the heavy and the other half for the fine works [23].

The periods for the heavy and the fine works are distributed among operations taking into account the amount of productions in each operation. The material, labor and machinery necessary for the completion of each operation within the prescribed period are calculated. The calculations are based on the unit cost analyses figures specified by the Ministry of Public Works [24]. Unit prices which form the activities, their resources and activity timing are given in the appendix 1.

The resource requirements for each operation is to be finished in the prescribed time are given in the appendix 1. The prescribed times, daily material needs, amount of labor and machinery are tabulated there in.

4.1. Project Planning Under No Resource Constraint

The initial and final nodal points and the times of duration for the project operations are fed into the program written in Visual Basic. As explained in the description of the algorithm, the parameters early start (ES), early finish (EF), late start (LS), late finish (LF), slack (S) in addition to the starting and finishing times of every activity (B and F respectively) are calculated by the program and thus appendix 2 is formed. After the calculation of the project activity data, the Gantt diagram relating to the project was drawn by program. In this diagram, the issues like which activity is to be performed in what period and what resources are to be needed on the daily basis are answered by the program. Under the conditions of no resource constraints, the program gave a final solution of 226 days, compared to the 240 days prescribed.

4.2. Project Planning Under Resource Constraints

Various methods are available for project planning under resource constraints. In this work, a heuristic method based on an algorithm making use of the priority rules is employed. The network of operations and the initial-and final nodal points of the project were determined. Early start (ES), early finish (EF), late start (LS), late finish (LF), slack (S) times the starting and finishing times of the individual activities (B and F respectively) is prepared after the calculation of the entries performed by the program.

The priority rule of presented algorithm, the period from the start of the activities to the end of the project (MRPL) was calculated by the program. The series of the IBPB values in increasing order are determined manually or by the program. Thus, programming for cases of constrained resources was carried out. Priorities for the MRPL values of the activities under the conditions of constrained resources were calculated by the program. In our project, the constrained values of the resources used for everyday are kept constant. These values were as follows:

- Cement : 15 tons/day
- Steel : 4 tons/day
- Bricks : 6000 piece/day
- Sand, gravel : 60 m^3/day
- Lumber : 15 m^3/day
- Unqualified worker : 25 persons/day
- Equipment craftsmen : 10 persons/day
- Concrete expert : 5 persons/day
- Woodwork craftsmen : 10 persons/day
- Wall craftsmen : 15 persons/day

- Excavator : 1 machine/day

The program produced the solutions with these constraints and the chosen priority rules. The starting and finishing times of every activity and the daily resource needs were calculated. With these limitations in hand, the period of the project was calculated to be 260 days.

5. Results and Suggestions

Project programming models with a small number of activities and resources can be worked out by mathematical models and the most accurate results can be reached in a reasonable length of time. However, in cases of complicated projects where a relatively large number of activities and resources are involved, the times required to reach a solution with these models make them useless. In these situations, algorithms working with simple rules are employed. These heuristic algorithms might not produce the most accurate solutions but they are still trustable with the near-optimum results.

Most studies relating to the construction project planning indicate a need for the use of heuristic algorithms. In this work, an algorithm based on the heuristic approach is used. A number of priority rules were subjected to performance tests. It is concluded that the performances of the priority rules vary to a considerable extent depending on the size of the network and the amount of resources. The priority rule used in this work is that the activity with the longest time of duration from the start to the end of the project (MRPL) is to be programmed first. An algorithm based on these assumptions was derived in the Visual Basic language.

The project of application comprises 79 activities each of which involving 11 different resources. Under the conditions of no resource constraint, the program calculates an overall period of 226 days for the heavy-and fine works. The extent of daily needs the resources were also calculated by the program. Under the conditions of constrained resources, the program gave a completion period of 260 days, 34 days longer compared to the case with no resource constraints. In work sides where the resources are insufficient or constraints on the material or labor exist, this approach may prove to be of value. In cases where the timely completion of the project or the optimization of the investment expenses is critical, this work is expected to shed some light.

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Appendix 1

No	i	j	t	Project Works	Type of Manufacturing	Unit	Quantity	Cement	Steel	Brick	Sand, gravel	Lumber	Layman	Equipment craftsman	Concrete expert	Woodwork craftsman	Wall craftsman	Excavator
1	1	2	10	Establishment of jobsite				1	2	3	4	5	6	7	8	9	10	11
2	2	3	7	A Block excavation	Machine excavation	m^3	2930						4					1
3	3	4	2	A Block below foundation base concrete	200 dosage base concrete	m^3	72	7,5			45		18		1			
4	4	5	10	A Block foundation reinforcement preparation	8-12 mm Ribbed steel	ton	14		3,5				5	8				
					14-26 mm Ribbed steel	ton	16,5											
5	5	7	3	A Block foundation reinforcement mounting	8-12 mm Ribbed steel	ton	14						5	8				
					14-26 mm Ribbed steel	ton	16,5											
6	4	6	1	A block foundation formwork preparation	Concrete having smooth surface, reinforced concrete formwork	m^2	480					6	3					
7	6	7	4	A block foundation formwork mounting	Concrete having smooth surface, reinforced concrete formwork	m^2	480						2			6		
8	7	8	8	A block foundation concrete	C 20 Concrete	m^3	291	13			44		10		3			
9	8	9	7	Cure of concrete														
10	9	10	3	A block foundation formwork removal	Concrete having smooth surface, reinforced concrete formwork	m^2	480						4					
11	10	11	3	A Block penning of above the foundation	Penning with quarry stone	m^3	72				27		6				3	
12	11	12	2	A Block base concrete of above the foundation	200 dosage base concrete	m^3	72	7,5			45		18		2			
13	12	13	5	A Block basement reinforcement preparation	8-12 mm Ribbed steel	ton	3,6		2				3	4				
					14-26 mm Ribbed steel	ton	4											
14	13	15	2	A Block basement reinforcement mounting	8-12 mm Ribbed steel	ton	3,6						3	4				
					14-26 mm Ribbed steel	ton	4											
15	12	14	2	A block basement formwork preparation	Concrete having smooth surface, reinforced concrete formwork	m^2	1395					8,5	4					
16	14	15	10	A block basement formwork mounting	Concrete having smooth surface, reinforced concrete formwork	m^2	1395					0,5	3	1		8		
					Wooden formwork scaffolding	m^3	2240											
17	15	16	6	A Block basement concrete	C 20 Concrete	m^3	178	11			36		8		3			
18	16	17	7	Cure of A Block concrete														

19	17	18	5	A block basement formwork removal	Concrete having smooth surface, reinforced concrete formwork	m²	1395						7					
20	18	19	5	A Block ground floor reinforcement preparation	8-12 mm Ribbed steel 14-26 mm Ribbed steel	ton ton	3,6 4		2				3	4				
21	19	21	2	A Block ground floor reinforcement mounting	8-12 mm Ribbed steel 14-26 mm Ribbed steel	ton ton	3,6 4						3	4				
22	18	20	2	A block ground floor formwork preparation	Concrete having smooth surface, reinforced concrete formwork	m²	1395					8,5	4					
23	20	21	10	A block ground floor formwork mounting	Concrete having smooth surface, reinforced concrete formwork Wooden formwork scaffolding	m² m³	1395 2240					0,5	3	1		8		
24	21	22	6	A Block ground floor concrete	C 20 Concrete	m³	178	11			36		8		3			
25	22	23	7	Cure of concrete														
26	23	24	5	A block ground floor formwork removal		m²	178						7					
27	24	25	5	A Block first floor reinforcement preparation	8-12 mm Ribbed steel 14-26 mm Ribbed steel	ton ton	3,5 4,5		2				3	4				
28	25	27	2	A Block first floor reinforcement mounting	8-12 mm Ribbed steel 14-26 mm Ribbed steel	ton ton	3,5 4,5						3	4				
29	24	26	2	A block first floor formwork preparation	Concrete having smooth surface, reinforced concrete formwork	m²	1550					9,5	5					
30	26	27	11	A block first floor formwork mounting	Concrete having smooth surface, reinforced concrete formwork Wooden formwork scaffolding	m² m³	1550 2240					0,4	3	1		8		
31	27	28	6	A Block first floor concrete	C 20 Concrete	m³	185	12			47		9		3			
32	28	29	7	Cure of concrete														
33	29	51	5	A Block first floor formwork removal	Concrete having smooth surface, reinforced concrete formwork	m²	1550						8					
34	2	30	2	B Block excavation	Machine excavation	m³	755						4					1
35	30	31	2	B Block below foundation base concrete	200 dosage base concrete	m³	63	6,5			40		16		1			
36	31	32	10	B Block foundation reinforcement preparation	8-12 mm Ribbed steel 14-26 mm Ribbed steel	ton ton	13 15,9		3,5				5	7				
37	32	34	3	B Block foundation	8-12 mm Ribbed steel	ton	13						5	7				

				reinforcement mounting	14-26 mm Ribbed steel	ton	15,9											
38	31	33	1	B Block foundation formwork preparation	Concrete having smooth surface, reinforced concrete formwork	m^2	496					3	3					
39	33	34	4	B Block foundation formwork mounting	Concrete having smooth surface, reinforced concrete formwork	m^2	496						2			6		
40	34	35	8	B Block foundation concrete	C 20 Concrete	m^3	321	15			49		10		3			
41	35	36		Cure of concrete														
42	36	37	3	B Block foundation formwork removal	Concrete having smooth surface, reinforced concrete formwork	m^2	496						4					
43	37	38	2	B Block penning of above the foundation	Penning with quarry stone	m^2	63				35		8				4	
44	38	39	2	B Block base concrete of above the foundation	200 dosage base concrete	m^3	63	6,5			40		16		1			
45	39	40	3	B Block ground floor reinforcement preparation	8-12 mm Ribbed steel	ton	3,5		3				4	6				
					14-26 mm Ribbed steel	ton	3,6											
46	40	42	1	B Block ground floor reinforcement mounting	8-12 mm Ribbed steel	ton	3,5						4	6				
					14-26 mm Ribbed steel	ton	3,6											
47	39	41	2	B Block ground floor formwork preparation	Concrete having smooth surface, reinforced concrete formwork	m^2	1242					7,5	4					
48	41	42	10	B Block ground floor formwork mounting	Concrete having smooth surface, reinforced concrete formwork	m^2	1242					0,5	3	1		7		
					Wooden formwork scaffolding	m^3	2016											
49	42	43	6	B Block foundation concrete	C 20 Concrete	m^3	147	9			30		7		2			
50	43	44	7	Cure of concrete														
51	44	45	4	B Block ground floor formwork removal	Concrete having smooth surface, reinforced concrete formwork	m^2	1242						8					
52	45	46	5	B Block first floor reinforcement preparation	8-12 mm Ribbed steel	ton	3,5		2				3	4				
					14-26 mm Ribbed steel	ton	4,5											
53	46	48	2	B Block first floor reinforcement mounting	8-12 mm Ribbed steel	ton	3,5						3	4				
					14-26 mm Ribbed steel	ton	4,5											
54	45	47	2	B Block first floor formwork preparation	Concrete having smooth surface, reinforced concrete formwork	m^2	1350					8,5	4					
55	47	48	10	B Block first floor formwork mounting	Concrete having smooth surface, reinforced concrete formwork	m^2	1350					0,5	3	1		8		
					Wooden formwork scaffolding	m^3	2016											
56	48	49	6	B Block first floor concrete	C 20 Concrete	m^3	155	9,5			33		7		2			

57	49	50		Cure of concrete														
58	50	51	4	B Block first floor formwork removal	Concrete having smooth surface, reinforced concrete formwork	m^2	1350						8					
59	51	52	10	Roof installation	Wooden roof structure	m^2	1326					6,6	10	1		10		
60	52	53	5	Roof covering	Marseilles roof coating	m^2	1326	0,6			2,4		12				8	
					Marseilles type brick	m	186											
					3 cm glass wool heat isolation	m^2	1326											
61	53	54	10	A Block inner outer brick wall	Brick wall installation	m^3	210	1		5775	4,5		11				4	
62	54	55	17	A Block inner plaster	Inner smooth plaster installation	m^2	650	11			29,5	0,2	6			1	8	
					Ceiling plaster	m^2	1920											
					Door frame	m^2	32											
63	55	57	3	A Block inner pointing works and wall coating	Plastic wall pointing	m^2	734	0,3			0,6		5				6	
					Wall coating with while faience	m^2	87											
64	54	57	3	A Block carpentry works	Single surfaced window making	m^2	256					0,25	3			2	4	
					Double surfaced plywood inner doormat	m^2	35											
65	54	56	13	A Block outer plaster	Outer plaster	m^2	1245	9			3	0,1	6			1	8	
					0-12.50 m work scaffolding	m^2	1100											
66	56	57	3	A Block outer pointing works	Acrylic based outer surface pointing	m^2	945						2				4	
67	57	58	4	A Block surface covering concrete	Concrete surface covering with 200 dosage cement	m^2	2048	2			10		12		3			
68	58	64	13	A Block floor covers	Floor coating with flat faience mosaic	m^2	1800	1			2,4		8				6	
					Faience coating of horizontal surfaces	m^2	180											
69	53	59	9	B Block inner outer brick wall	Brick wall installation	m^3	195	1		5960	3,5		11				4	
70	59	60	11	B Block inner plaster	Inner smooth plaster installation	m^2	580	11			26,5	0,2	6			1	8	
					Ceiling plaster	m^2	1088											
					Door frame	m^2	24											
71	60	62	2	B Block inner pointing works and wall coating	Plastic wall pointing	m^2	366	0,2			0,4		4				4	
					Wall coating with while faience	m^2	43											
72	59	62	3	B Block carpentry works	Single surfaced window making	m^2	256					0,25	3			2	4	
					Double surfaced plywood inner doormat	m^2	35											

73	59	61	8	B Block outer plaster	Outer plaster	m²	790	9			3	0,1	6			1	8	
					0-12.50 m work scaffolding	m²	740											
74	61	62	3	B Block outer pointing works	Acrylic based outer surface pointing	m²	945						2				4	
75	62	63	3	B Block surface covering concrete	Concrete surface covering with 200 dosage cement	m²	1024	1			5,5		6		5			
76	63	64	7	B Block floor covers	Floor coating with flat faience mosaic	m²	1000	0,5			1,2		5				4	
					Faience coating of horizontal surfaces	m²	92											
77	64	65	4	Thin metal works	Horizontal rain water gutter with 12 no zinc	m	216						9	2			7	
					Vertical rain water gutter with 12 no zinc	m	168											
78	65	66	4	Window glass installation	3 mm thick window glass	m²	512						2			6		
79	66	67	10	Environmental and contractor works														

Appendix 2. Project activity data

No	Type of Manufacturing	Critical Activity	t	ES	EF	LS	LF	S	B	F	MRP L	Priority order
1	Establishment of jobsite	E	10	0	10	0	10	0	0	10	226	1
2	Excavation	E	7	10	17	10	17	0	10	17	216	2
3	Below foundation base concrete	E	2	17	19	17	19	0	17	19	209	3
4	Foundation reinforcement preparation	E	10	19	29	19	29	0	19	29	207	4
5	Foundation reinforcement mounting	E	3	29	32	29	32	0	29	32	197	7
6	Foundation formwork preparation	H	1	17	18	27	28	10	17	18	199	5
7	Foundation formwork mounting	H	4	18	22	28	32	10	18	22	198	6
8	Foundation concrete	E	8	32	40	32	40	0	32	40	194	8
9	Cure of concrete	E	7	40	47	40	47	0	40	47	186	9
10	Foundation formwork removal	E	3	47	50	47	50	0	47	50	179	10
11	Penning of above the foundation	E	3	50	53	50	53	0	50	53	176	12
12	Base concrete of above the foundation	E	2	53	55	53	55	0	53	55	173	14
13	Basement reinforcement preparation	H	5	55	60	60	65	5	55	60	166	18
14	Basement reinforcement mounting	H	2	60	62	65	67	5	60	62	161	22
15	Basement formwork preparation	E	2	55	57	55	57	0	55	57	171	16
16	Basement formwork mounting	E	10	57	67	57	67	0	57	67	169	17
17	Basement concrete	E	6	67	73	67	73	0	67	73	159	24
18	Cure of concrete	E	7	73	80	73	80	0	73	80	153	25
19	Basement formwork removal	E	5	80	85	80	85	0	80	85	146	27
20	Ground floor reinforcement preparation	H	5	85	90	90	95	5	85	90	136	34
21	Ground floor reinforcement mounting	H	2	90	92	95	97	5	90	92	131	36
22	Ground floor formwork preparation	E	2	85	87	85	87	0	85	87	141	30
23	Ground floor formwork mounting	E	10	87	97	87	97	0	87	97	139	32
24	Ground floor concrete	E	6	97	103	97	103	0	97	103	129	38
25	Cure of concrete	E	7	103	110	103	110	0	103	110	123	39
26	Ground floor formwork removal	E	5	110	115	110	115	0	110	115	116	43
27	First floor reinforcement preparation	H	5	115	120	121	126	6	115	120	105	49
28	First floor reinforcement mounting	H	2	120	122	126	128	6	120	122	100	51
29	First floor formwork preparation	E	2	115	117	115	117	0	115	117	111	45
30	First floor formwork mounting	E	11	117	128	117	128	0	117	128	109	46
31	First floor concrete	E	6	128	134	128	134	0	128	134	98	53
32	Cure of concrete	E	7	134	141	134	141	0	134	141	92	55
33	First floor formwork removal	E	5	141	146	141	146	0	141	146	85	57
34	Excavation	H	2	10	12	49	51	39	10	12	177	11
35	Below foundation base concrete	H	2	12	14	51	53	39	12	14	175	13
36	Foundation reinforcement preparation	H	10	14	24	53	63	39	14	24	173	15
37	Foundation reinforcement mounting	H	3	24	27	63	66	39	24	27	163	21
38	Foundation formwork preparation	H	1	14	15	61	62	47	14	15	165	19
39	Foundation formwork mounting	H	4	15	19	62	66	47	15	19	164	20
40	Foundation concrete	H	8	27	35	66	74	39	27	35	160	23
41	Cure of concrete	H	7	35	42	74	81	39	35	42	152	26
42	Foundation formwork removal	H	3	42	45	81	84	39	42	45	145	28
43	Penning of above the foundation	H	2	45	47	84	86	39	45	47	142	29
44	Base concrete of above the foundation	H	2	47	49	86	88	39	47	49	140	31
45	Ground floor reinforcement preparation	H	3	49	52	96	99	47	49	52	130	37
46	Ground floor reinforcement mounting	H	1	52	53	99	100	47	52	53	127	40
47	Ground floor formwork preparation	H	2	49	51	88	90	39	49	51	138	33
48	Ground floor formwork mounting	H	10	51	61	90	100	39	51	61	136	35

49	Foundation concrete	H	6	61	67	100	106	39	61	67	126	41
50	Cure of concrete	H	7	67	74	106	113	39	67	74	120	42
51	Ground floor formwork removal	H	4	74	78	113	117	39	74	78	113	44
52	First floor reinforcement preparation	H	5	78	83	122	127	44	78	83	104	50
53	First floor reinforcement mounting	H	2	83	85	127	129	44	83	85	99	52
54	First floor formwork preparation	H	2	78	80	117	119	39	78	80	109	47
55	First floor formwork mounting	H	10	80	90	119	129	39	80	90	107	48
56	First floor concrete	H	6	90	96	129	135	39	90	96	97	54
57	Cure of concrete	H	7	96	103	135	142	39	96	103	91	56
58	First floor formwork removal	H	4	103	107	142	146	39	103	107	84	58
59	Roof installation	E	10	146	156	146	156	0	146	156	80	59
60	Roof covering	E	5	156	161	156	161	0	156	161	70	60
61	A Block brick wall	E	10	161	171	161	171	0	161	171	65	61
62	A Block inner plaster	E	17	171	188	171	188	0	171	188	55	62
63	A Block inner pointing works and wall coating	E	3	188	191	188	191	0	188	191	38	67
64	A Block carpentry works	H	3	171	174	188	191	17	171	174	38	68
65	A Block outer plaster	H	13	171	184	175	188	4	171	184	51	64
66	A Block outer pointing works	H	3	184	187	188	191	4	184	187	38	69
67	A Block surface covering concrete	E	4	191	195	191	195	0	191	195	35	70
68	A Block floor covers	E	13	195	208	195	208	0	195	208	31	74
69	B Block inner outer brick wall	H	9	161	170	176	185	15	161	170	50	63
70	B Block inner plaster	H	11	170	181	185	196	15	170	181	41	65
71	B Block inner pointing works and wall coating	H	2	181	183	196	198	15	181	183	30	73
72	B Block carpentry works	H	3	170	173	195	198	25	170	173	31	71
73	B Block outer plaster	H	8	170	178	187	195	17	170	178	39	66
74	B Block outer pointing works	H	3	178	181	195	198	17	178	181	31	72
75	B Block surface covering concrete	H	3	183	186	198	201	15	183	186	28	75
76	B Block floor covers	H	7	186	193	201	208	15	186	193	25	76
77	Thin metal works	E	4	208	212	208	212	0	208	212	18	77
78	Window glass installation	E	4	212	216	212	216	0	212	216	14	78
79	Environmental and contractor works	E	10	216	226	216	226	0	216	226	10	79